
# *TEXAS III Presentation*

## Technical eXchange on AIS via Satellite

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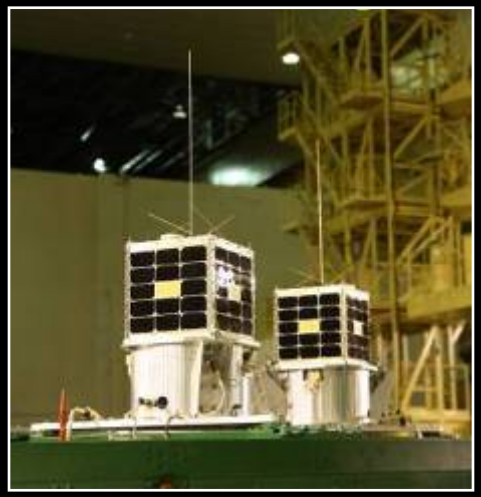
# SpaceQuest, Ltd.

www.spacequest.com

Dnepr Space Head

- Founded 1994 in Fairfax, Virginia
- Focused on microsatellite technologies. (40 spacecrafts to date)
- Built and launched Microsats for LatinSat, Aprize, AMSAT, others.
- Provides Microsat subsystems to NASA, Canadian Space Agency, US Air Force, US Navy, US Aerospace Corporations, Universities, and Foreign Space Agencies.
- Developed all avionics & software for Bigelow Aerospace.
- Conducted many component flight qualifications programs.

AprizeSat-3

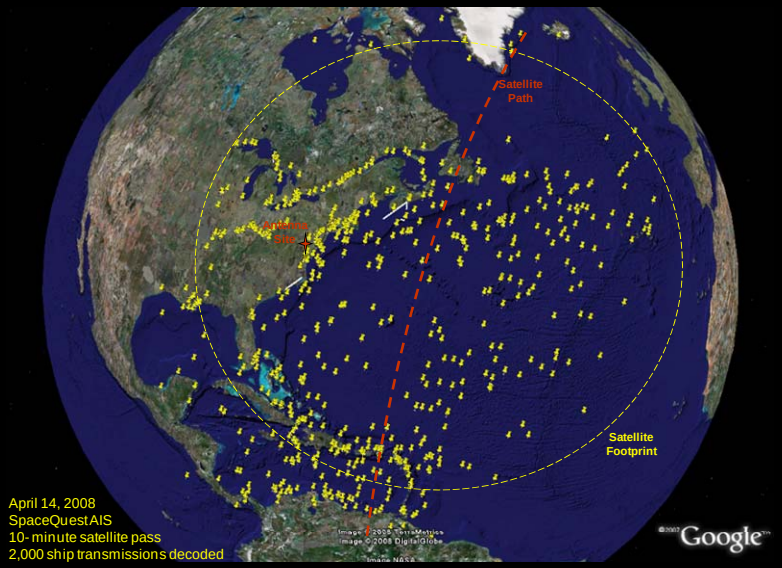


AprizeSats-3 and 4

AprizeSat-4

# TEXAS II Presentation

- In 2007 SpaceQuest placed an AIS transponder in orbit.
- Brought AIS signal from space to Earth via S-Band analog downlink.
- Briefed results of signal analysis at TEXAS II Conference.
- Learned what was needed to construct an effective AIS decoder for space.




April 14, 2008
SpaceQuest AIS
10- minute satellite pass
2,000 ship transmissions decoded

# Update from TEXAS II Conference

*During the past 12 months SpaceQuest:*

- Designed and developed advanced AIS hardware and flight software.
- Built and tested three space-qualified AIS satellites in 10-months.
- Launched two AIS spacecraft on July 29th (AprizeSats 3 & 4).
- AprizeSat-5 is a ground-based software development test bed.
- Commissioned both satellites autonomously during the first orbit, and began collecting AIS data globally.
- Contacted both satellites from our ground station in Fairfax, Virginia during the first visible pass 7-hours after launch.
- Downloaded and analyzed AIS & telemetry data using both UHF and S-Bands.

Note: These activities were completed without any outside funding.

# SpaceQuest Microsatellite Bus

Mission: M2M Data with auxiliary AIS payload

- 13 kg, 25 cm cubes
- 10+ years orbital lifetime
- Low-cost, high performance
- Inexpensive piggyback launch
- Autonomous operation
- Store-and-Forward Data Collection
- Global AIS Receivers

Aprize satellites on Dnepr Space Head Module

# Satellite Development Schedule

| | |
|---|---|
| Mar 2008 | Sign launch contract with Kosmotras |
| Sep 2008 | Start construction of spacecraft components |
| Mar 2009 | Complete Aprize Flatsat |
| May 2009 | Assemble flight trays for AprizeSat-3 and 4 |
| June 2009 | Integrate Flight Trays and perform functional tests |
| July 2009 | Mount solar panes, perform thermal cycle and vacuum tests |
| July 05, 09 | Transport spacecraft to Baikonur Cosmodrome |
| July 15, 09 | Prepare satellites at launch complex & mount on space head |
| July 17, 09 | Integrate primary spacecraft, close fairing and move to launch silo |
| July 29, 09 | Launch satellites and start collecting AIS messages |
| July 30, 09 | Download AIS data and telemetry from both spacecraft |

# AprizeSat Construction & Launch Integration


AprizeSat-3 Without wiring Harness

AS-3 and AS-4 on Launch Platform

# Dnepr Space Head Module Encapsulation


July 16, 2009; Baikonur, Kazakhstan

# SpaceQuest's AIS Payloads

## Flight Computer Tray

- Spacecraft Flight Computer
- ARM-7 µProcessor
- ADC/DAC Interface,
- Power PC FPGA running LINUX

## AIS Experiment Tray

- Two fixed Channel AIS Receivers
- Agile AIS Receiver
- Dual-Channel Downconverter
- Input-Output Switching Matrix
- GPS Receiver

# AIS Payload Capabilities

## AIS Payloads:

2 AIS monopole antennas

2 dual-channel AIS receivers with -125 dBm sensitivity

1 frequency-agile AIS receiver with -120 dBm sensitivity

1 frequency-agile 1-Watt S-Band transmitter up to 500 Kbps

2 UHF frequency-agile, 2 to 4 Watt transmitters up to 38.8 Kbps

2 independent AIS µprocessor recorders with 5GB of data storage

1 dual-channel down-converter with mixing and converting to various IF's or baseband

1 audio switching matrix  to switch any input to any output with gain & filter controls

1 14-Channel GPS receiver for precise location and time

## AprizeSats also contain:

- Four M2M Receivers and Two UHF Transmitters.
- Several SpaceQuest components for space qualification.

# AIS Operating Modes

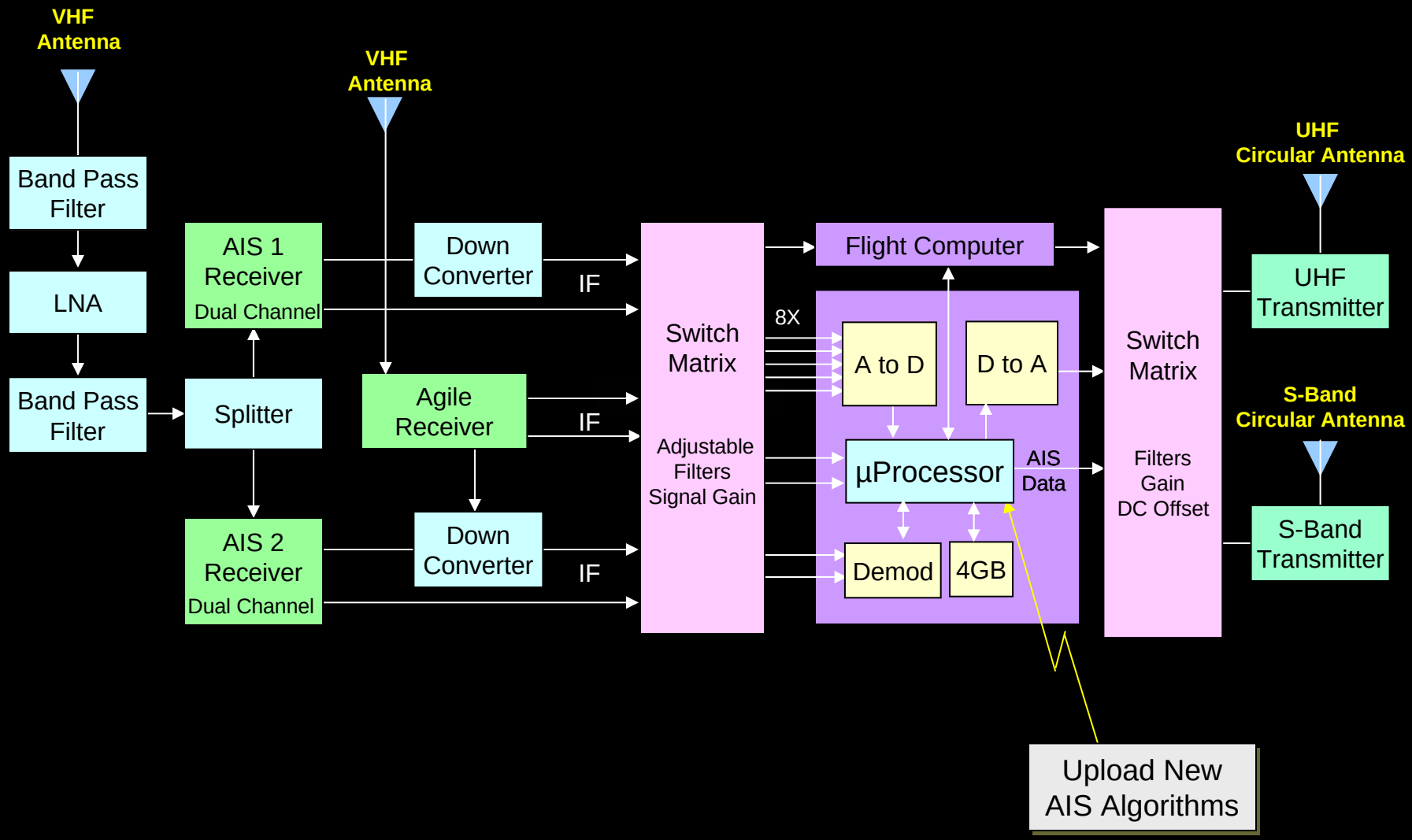
## Processing Modes:

- Digitize and store both AIS Channels using the ARM-7 or Power PC.
- Decode AIS signals in real-time or post-process later.
- Transpond raw analog signals or download digitized data using UHF or S-Band.
- Upload new processing algorithms as required.

## Download Modes:

- Real-Time or Store-and-Forward
- Analog or Digital Data
- Raw AIS Signals or Decoded Data
- Download AIS data using:
  - High-speed UHF transmitter, or
  - S-Band transmitter up to 500 Kbps

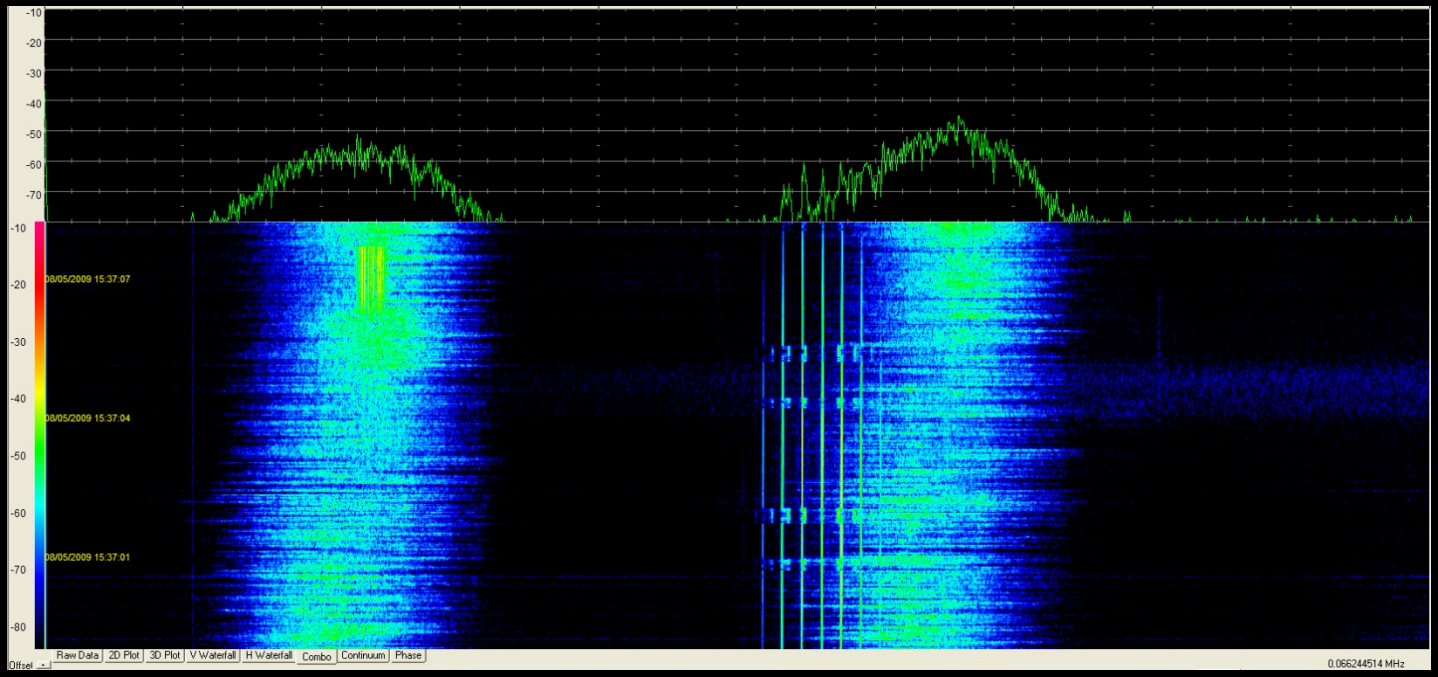
# Simple Block Diagram of AIS Payload



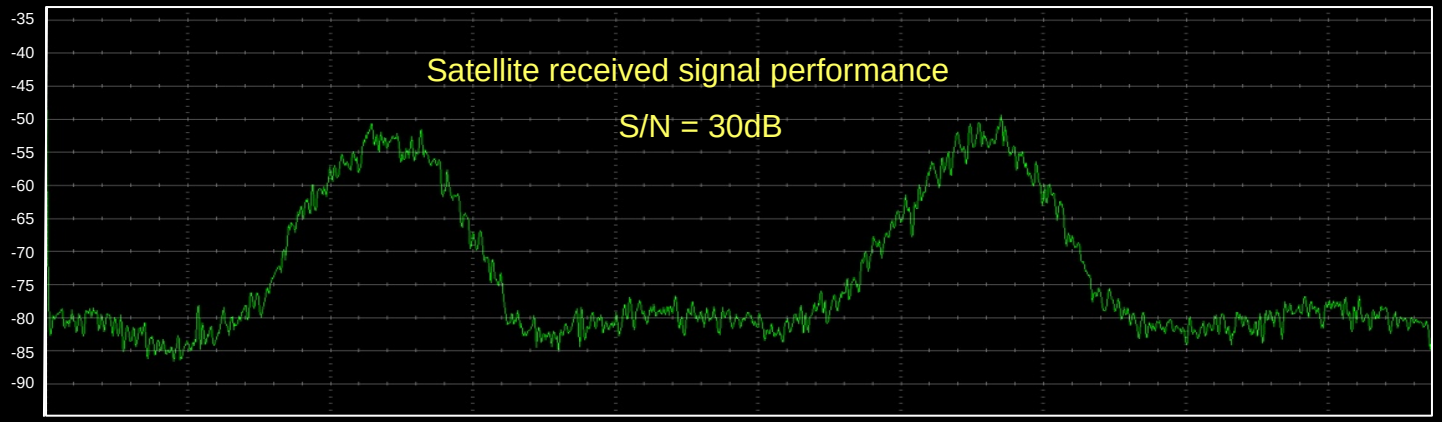
# Functional Capabilities of AIS Payloads

- Receive and transpond both AIS signals in real time via UHF or S-Band downlinks
- Receive, digitize and store AIS signals from anywhere on Earth
- Convert digital data to analog and transmit via UHF or S-Band
- Decode both AIS channels in real time for on-board storage or real-time transmit
- Vary sampling rates, filtering and RF gains on board the satellite
- Perform worldwide spectrum survey of AIS frequencies and amplitude levels
- Use AIS data from space to develop and test new AIS algorithms
- Upload new AIS firmware  to satellite data processors in space
- Sufficient power to operate AIS receivers and data processor continuously
- Download analog or digital AIS data to many ground stations around the world
- UHF or S-Band transmitter can operate for 15minutes or more on every orbit

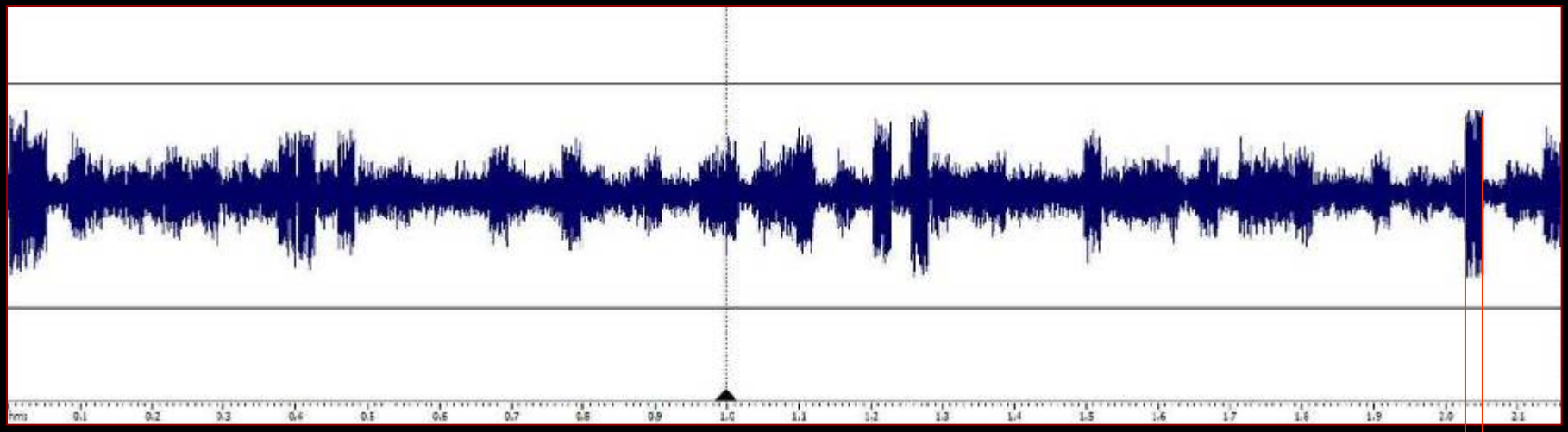
# Spectral Plot of Wideband Analog Signal in AIS Bands

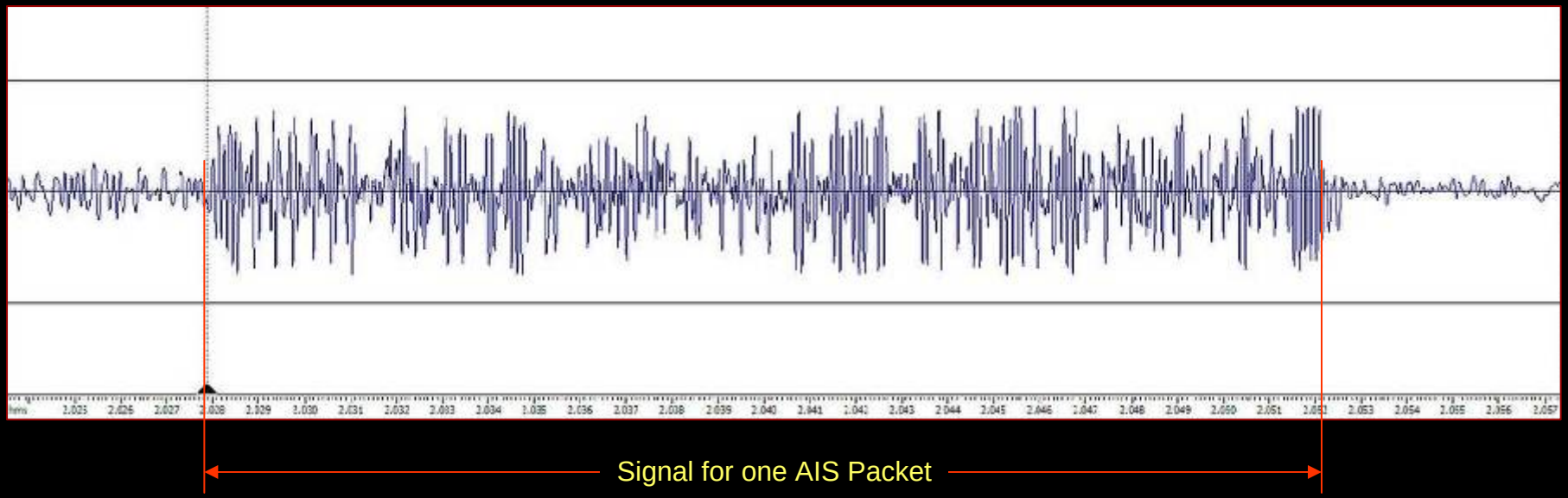



AIS analog signals received using NRL S-Band antenna at Blossom Point, MD.



# AIS Signal Structure from Space



# Some Early Results

*Initial AIS Operations:*

- AprizeSat-3 and 4 were commissioned 1 hour after separation.
- Both AIS payloads were activated and began collecting data on their second orbit.
- Over 200,000 AIS transmissions were captured and decoded in the first 160 minutes.
- The average AIS data collection rate for the first 1½ orbits was 20 reading/second.

*Follow-up AIS Activities:*

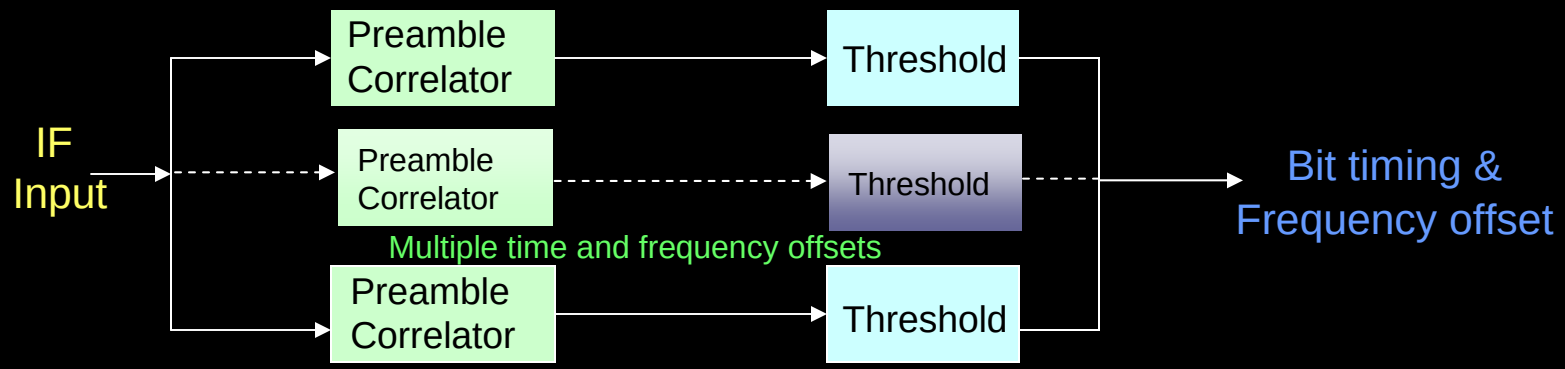
- *Analog transponder mode:* Received two-channel AIS signal; download on S-Band.
- *Digital storage mode:* Digitize and store AIS raw data on-board; download on UHF.
- *Receive and store:* Receive, process, decode and store; download later on UHF.

*On-board Processing:*

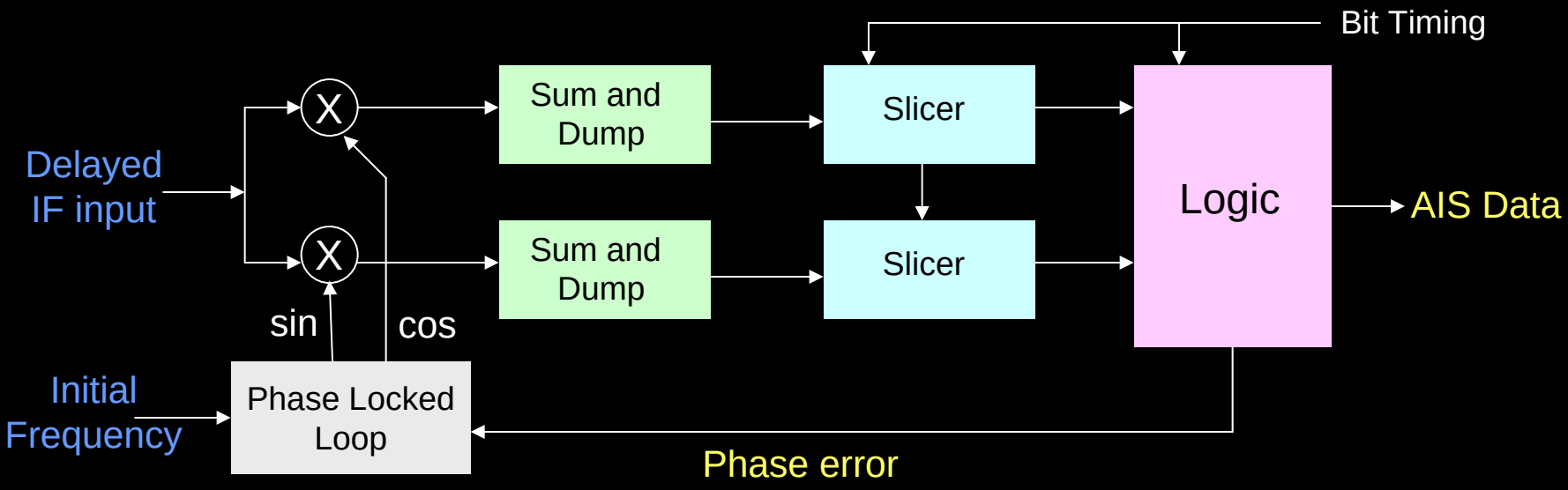
- Search for preamble and flags by correlating with known training sequence.
- Identify AIS signal frequency and time delay.
- Demodulate signal coherently and capture AIS data.

# FPGA Demodulator

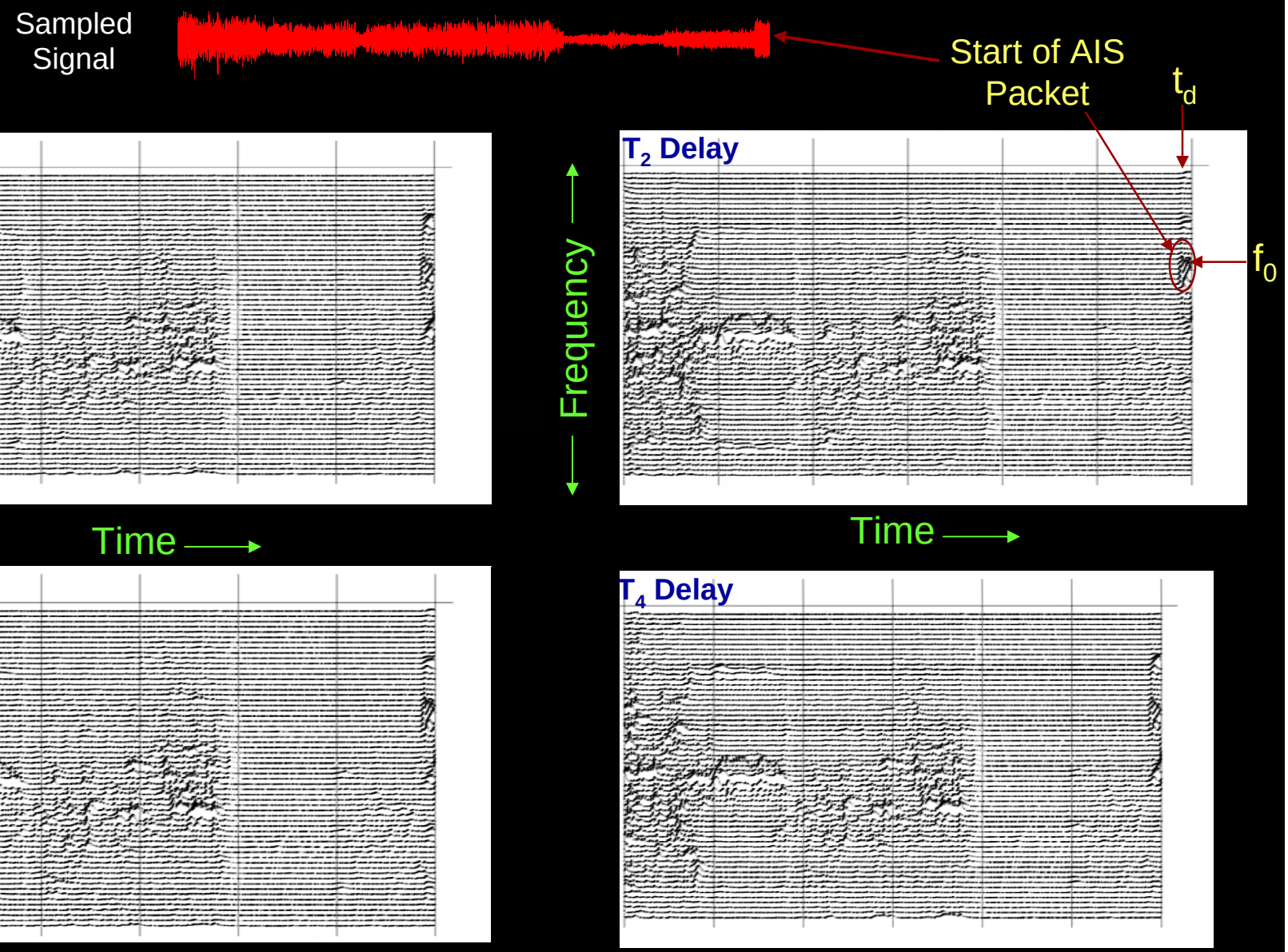
- Use multiple correlation receivers to detect preamble frequency and timing




- Demodulate coherently to increase ability to detect overlapping packets



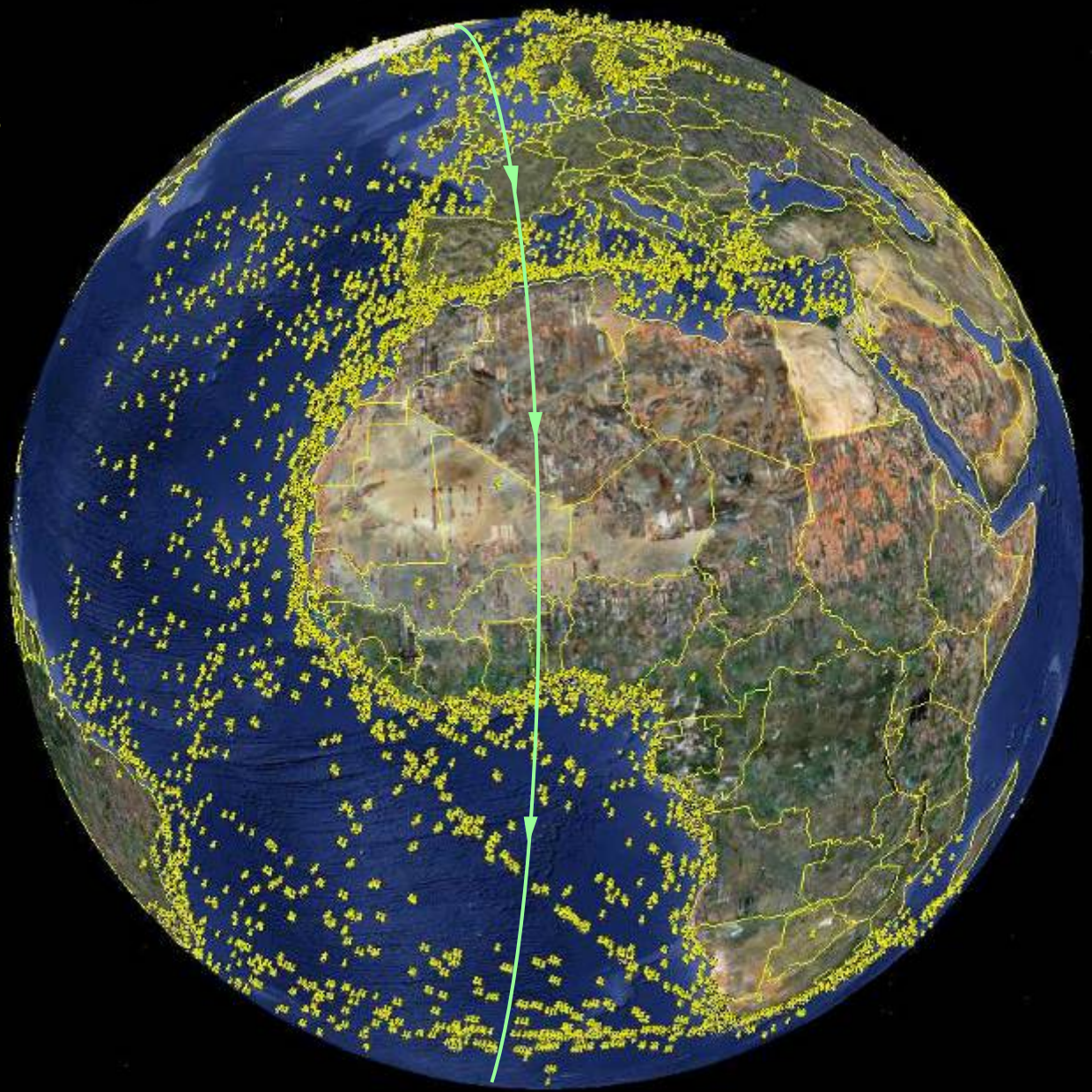
# Frequency and Timing Offsets Example



# First North-South Orbit of AprizeSats

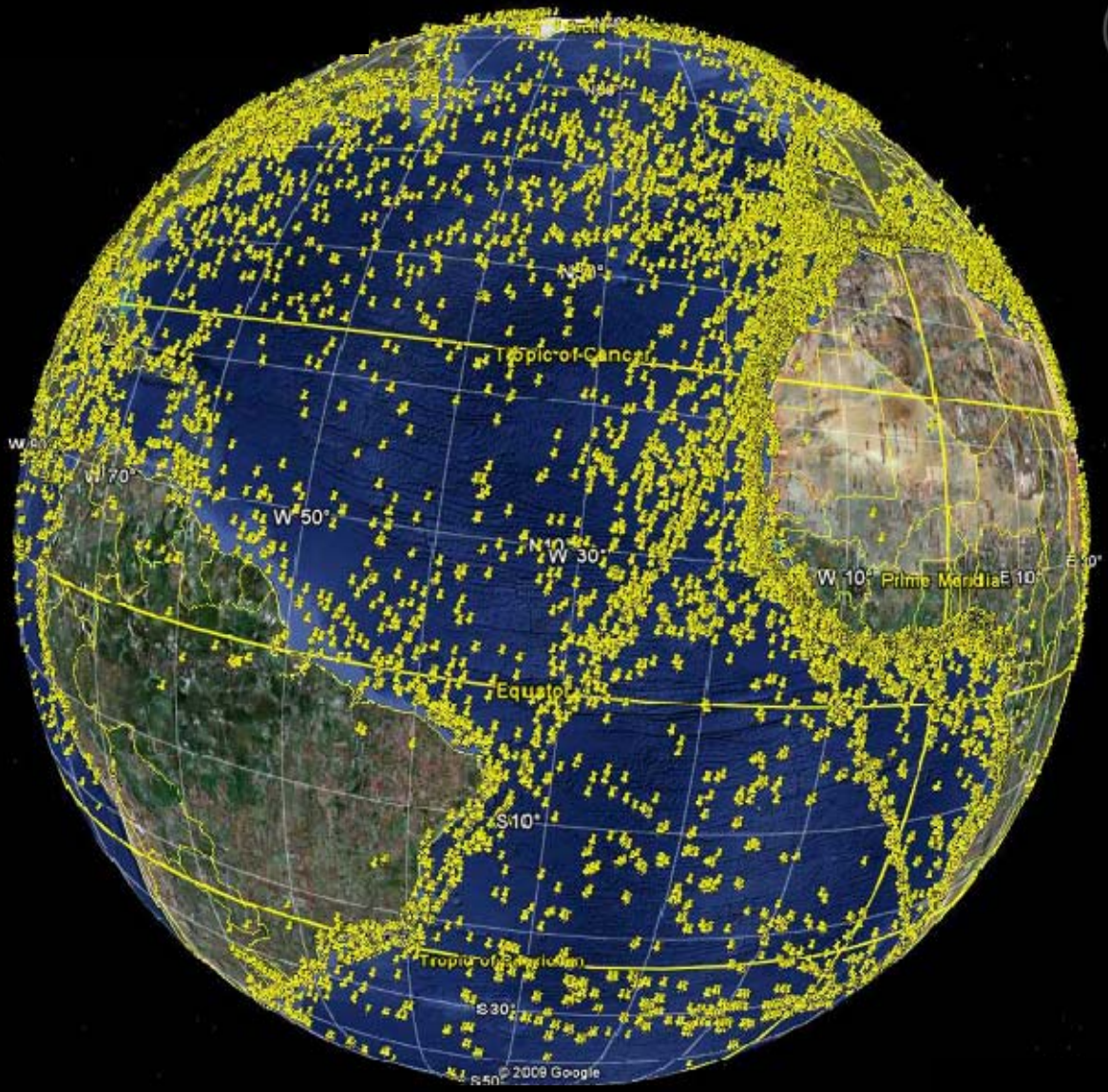
July 29, 2009

200,000 Messages
In 160 Minutes
2 Channels
2 Satellites



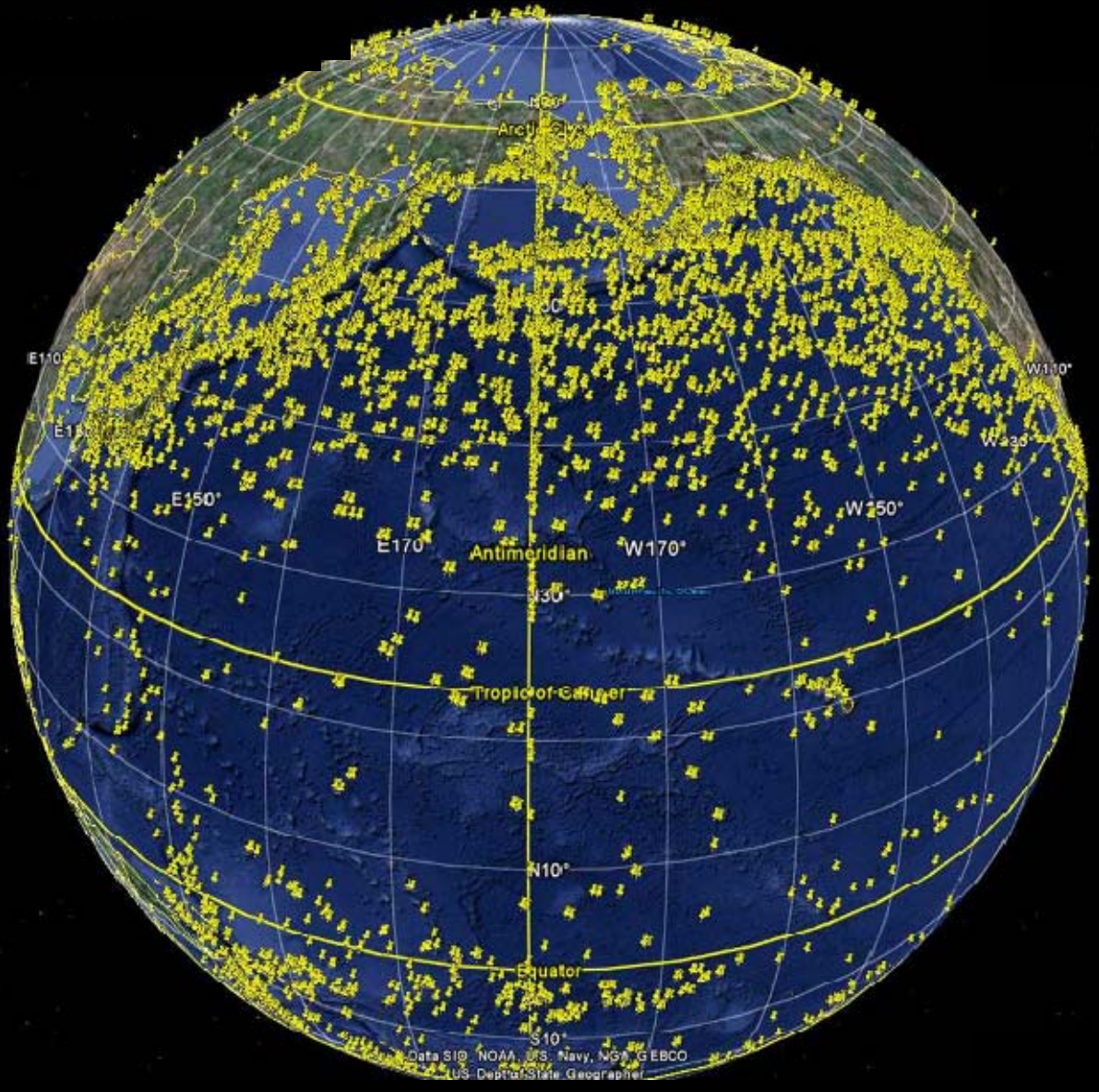
# Close Up of the Mediterranean Sea (First Orbit)

# Atlantic Ocean

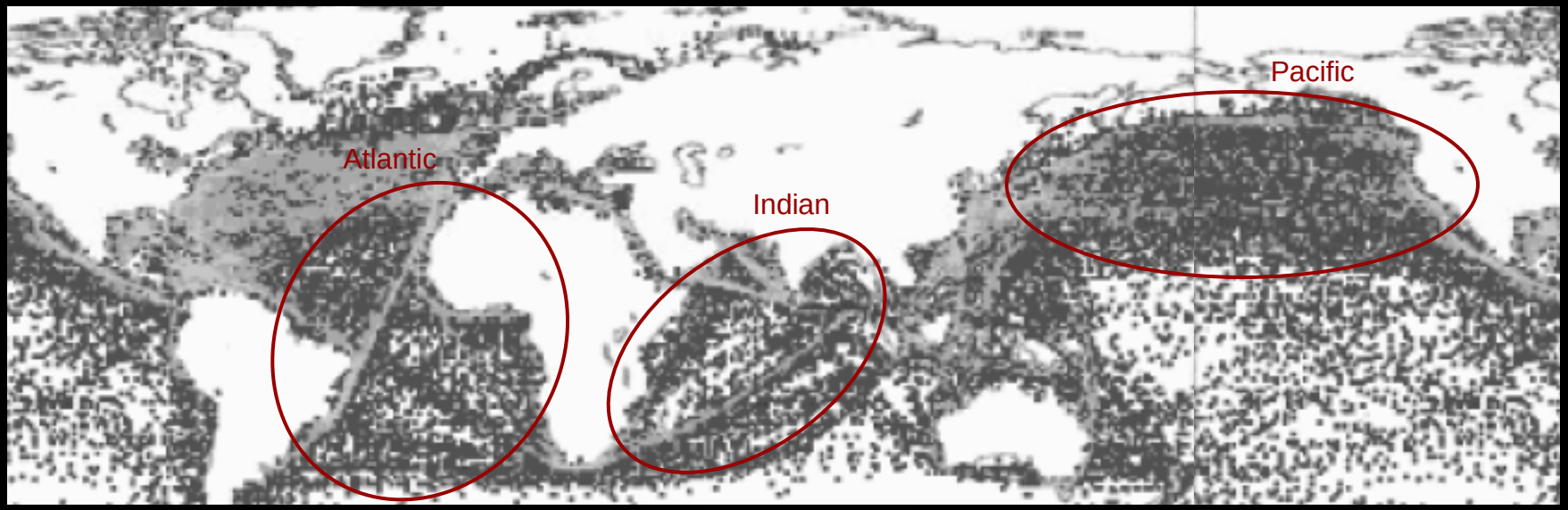


# Indian Ocean

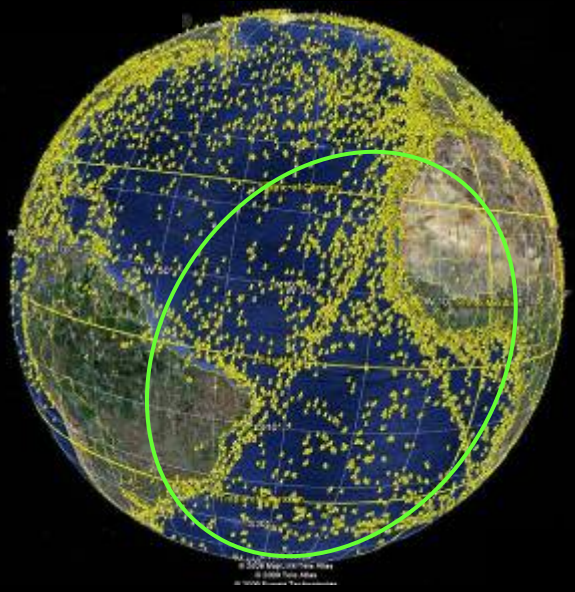
# Pacific Ocean



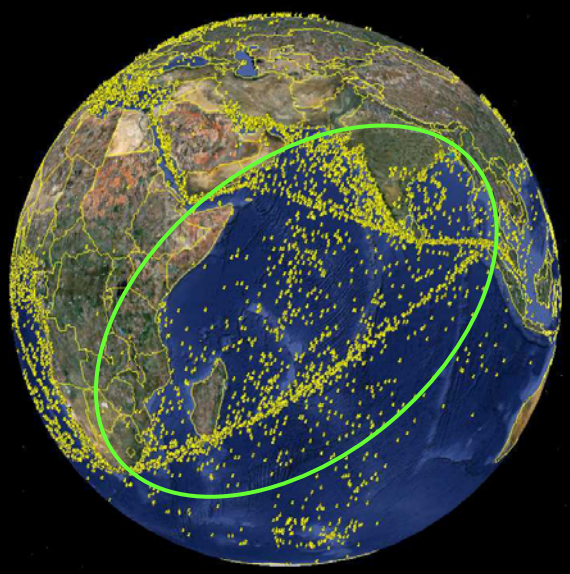
# Ship Traffic Density Model Vs AIS Measurements



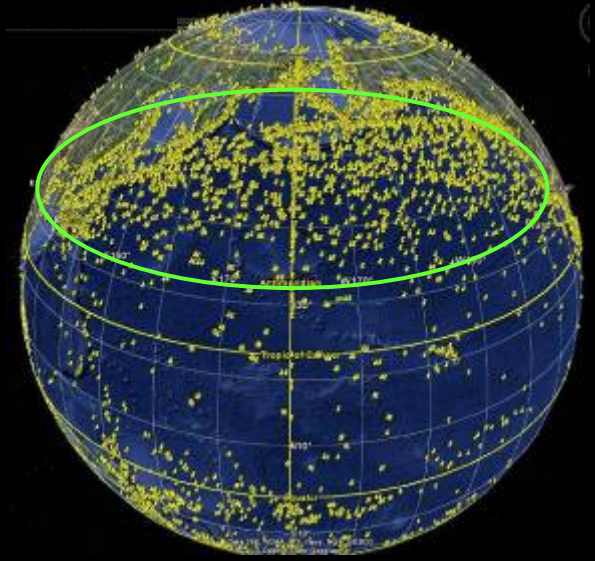

Atlantic Ocean



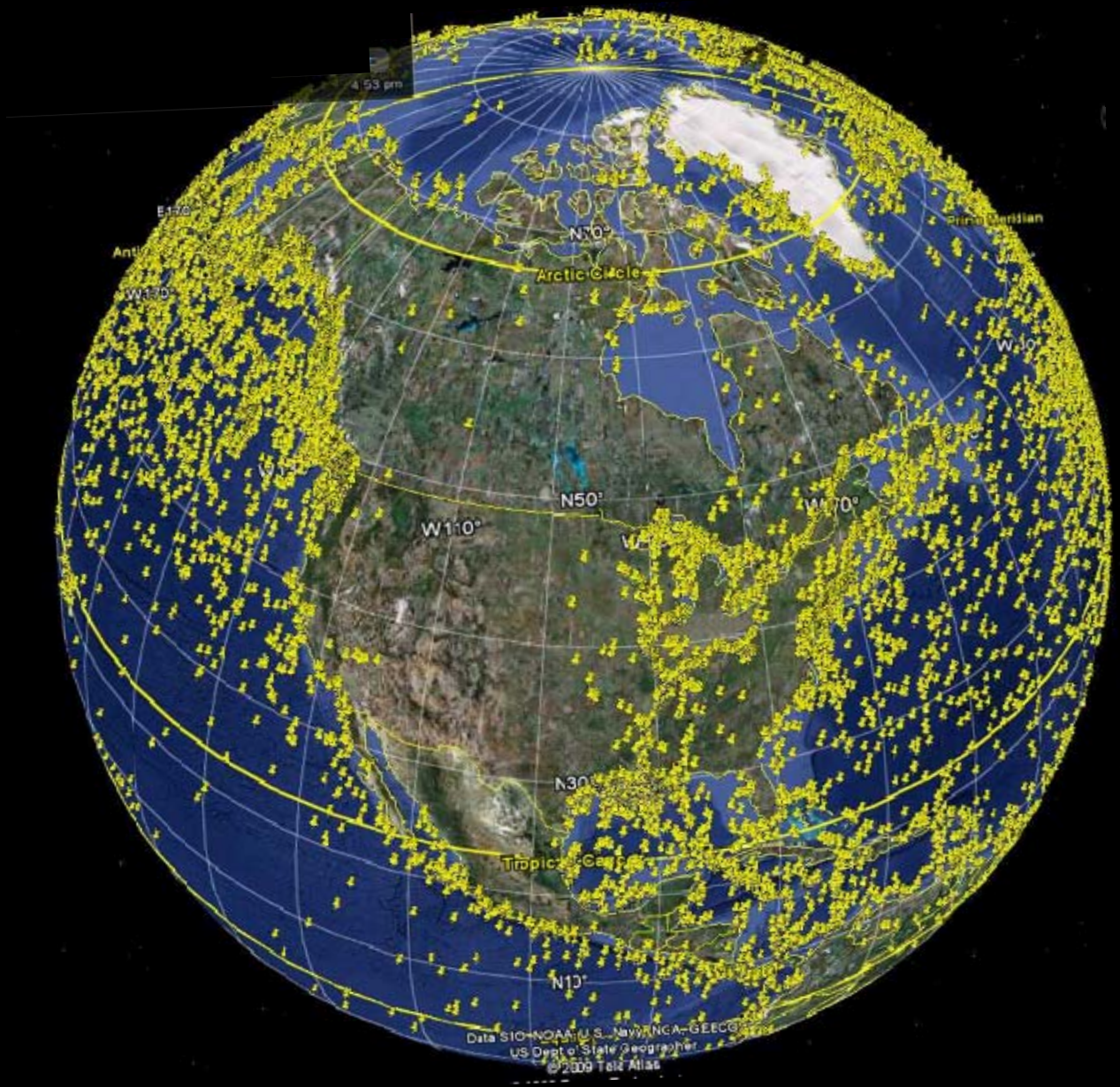
Indian Ocean



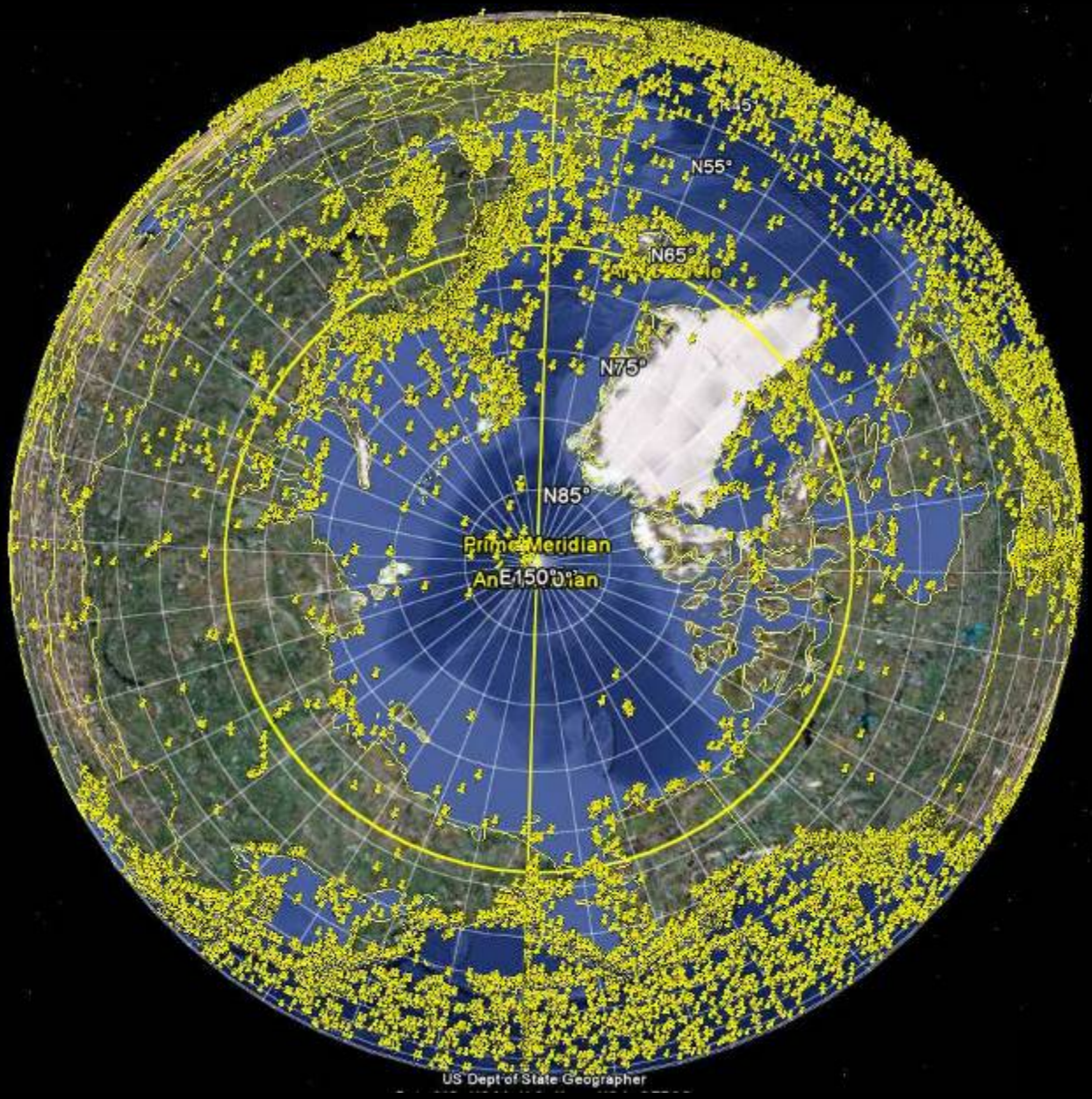
Pacific Ocean



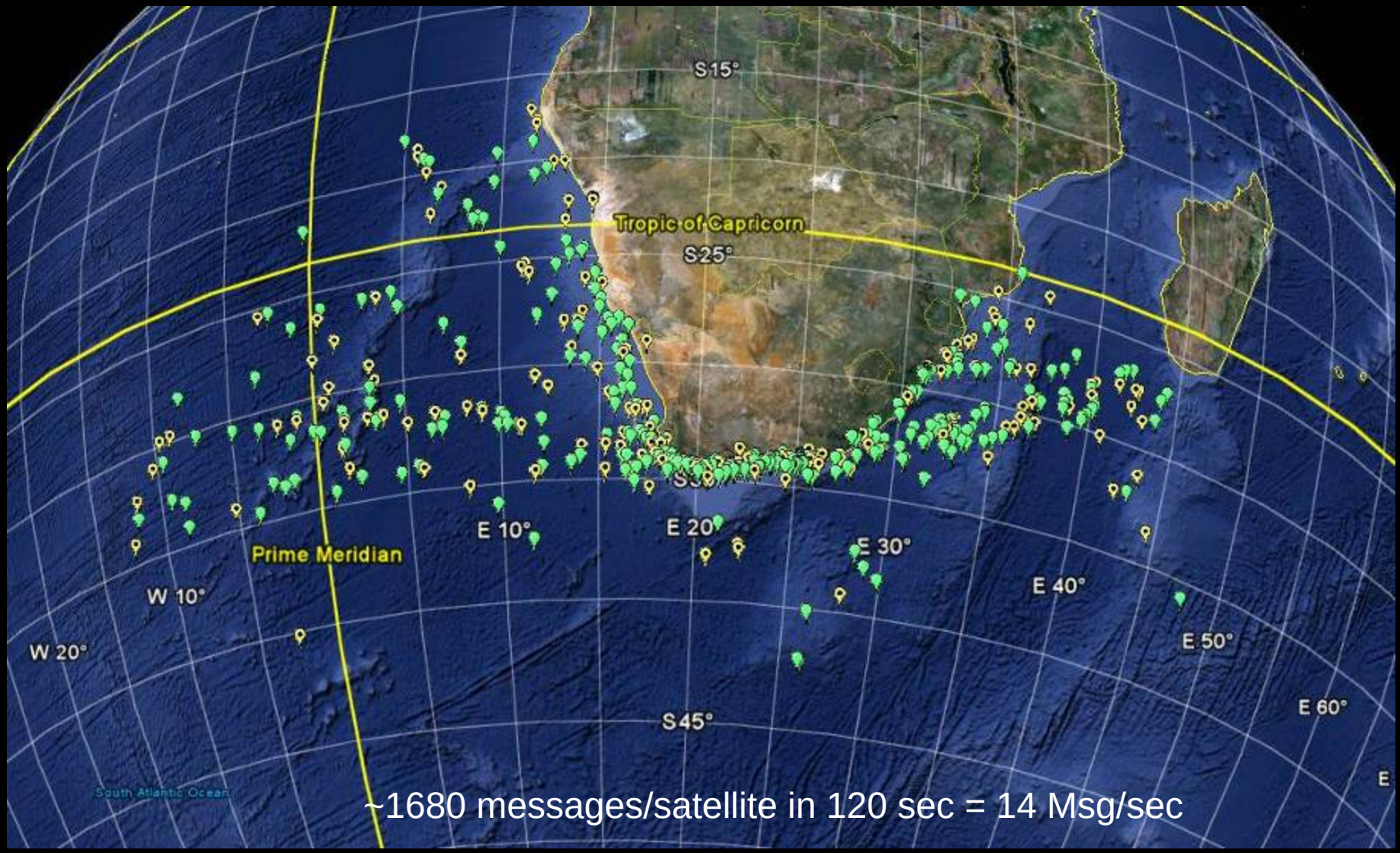
# North America



# View over the North Pole



# Two-Minutes of AIS Data - South Africa

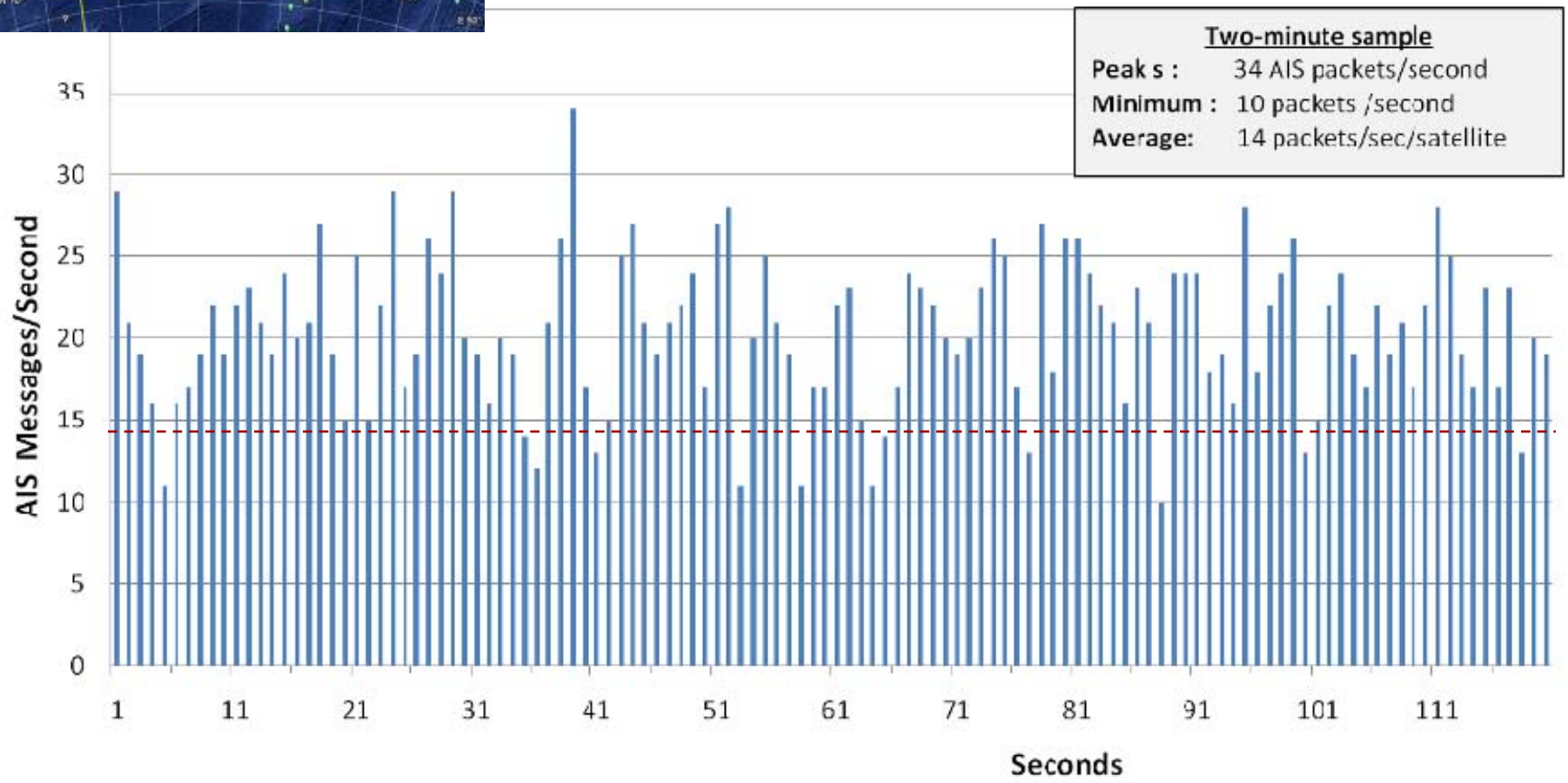



Yellow = AprizeSat-3

Green = AprizeSat-4

# AIS Message Reception Rate

## AIS Messages/Second Received by AprizeSat-3

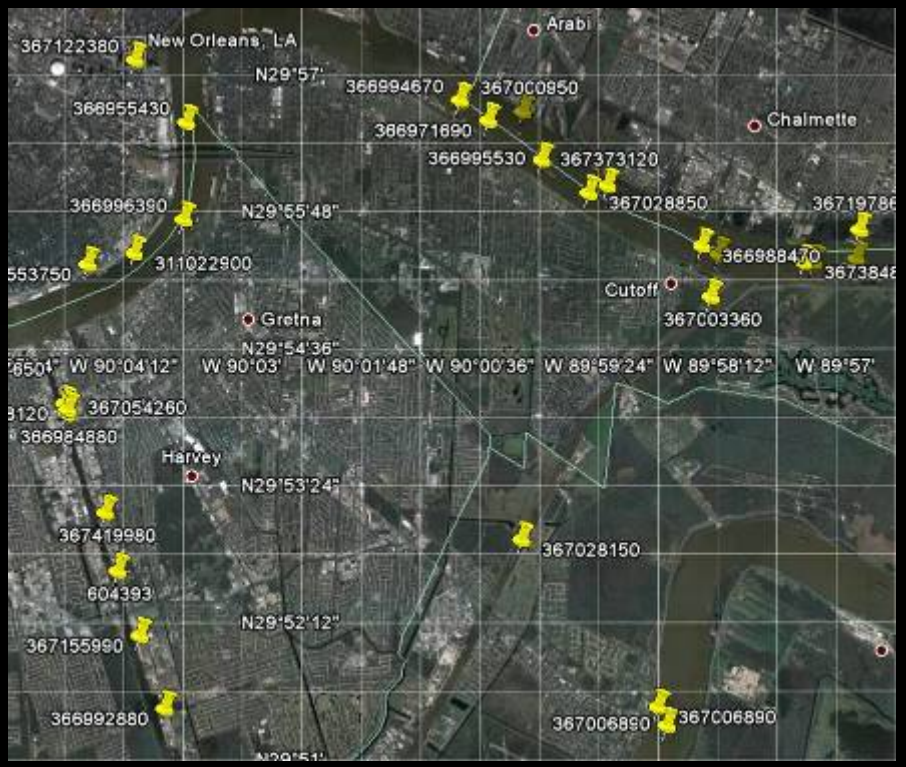


# Comparison of AIS Messages from New Orleans Harbor

3-minute flyby of AprizeSat-3
August 11, 2009

Mississippi River in New Orleans


Port Vision (103 unique ships)




SpaceQuest (25 unique ships)

25/103 = 24.3%

# Aprize Satellites Cover a Much Broader Region


AIS data from Port Vision

Two-minute flyover by AprizeSat

# Comparison of AIS Messages from Seattle Harbor

portvision


Port Vision - 83 unique ships

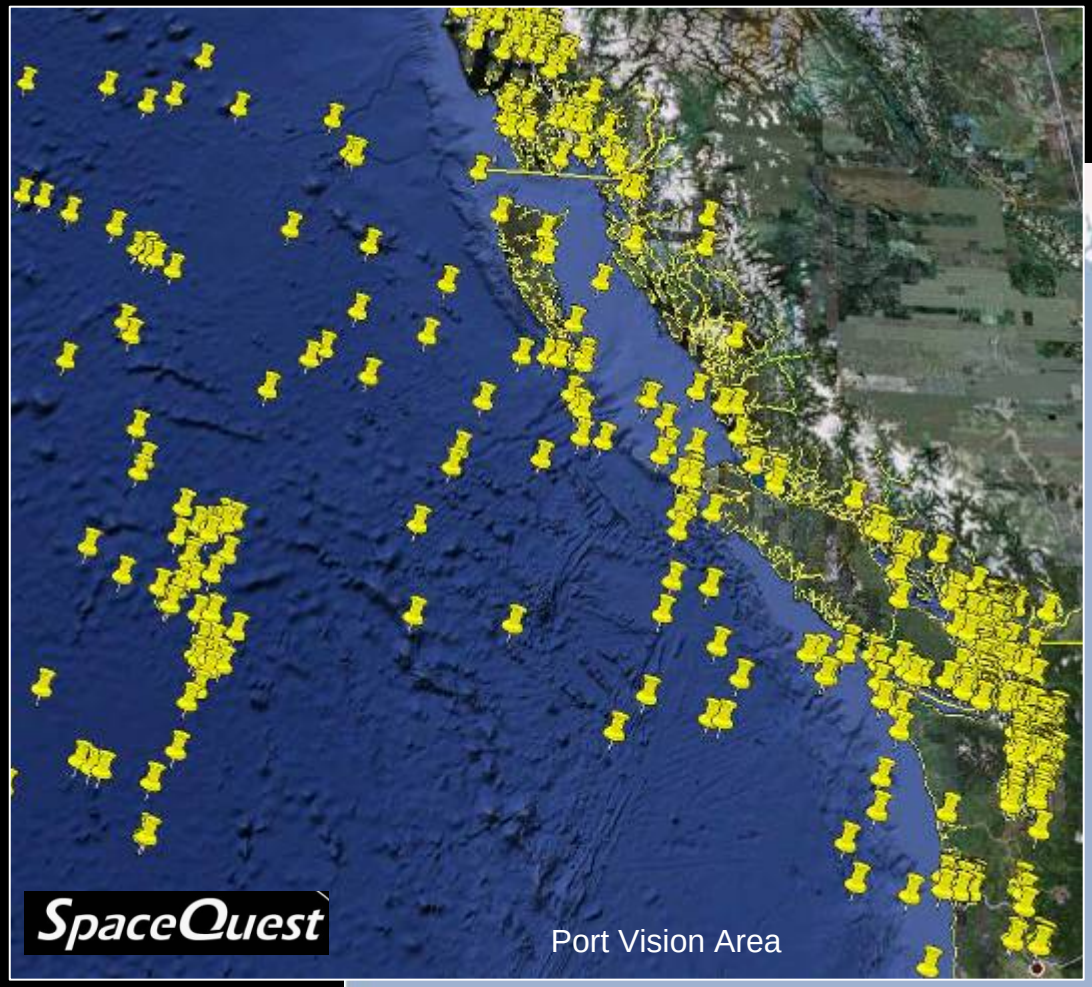
**16 same; 15 new**

SpaceQuest

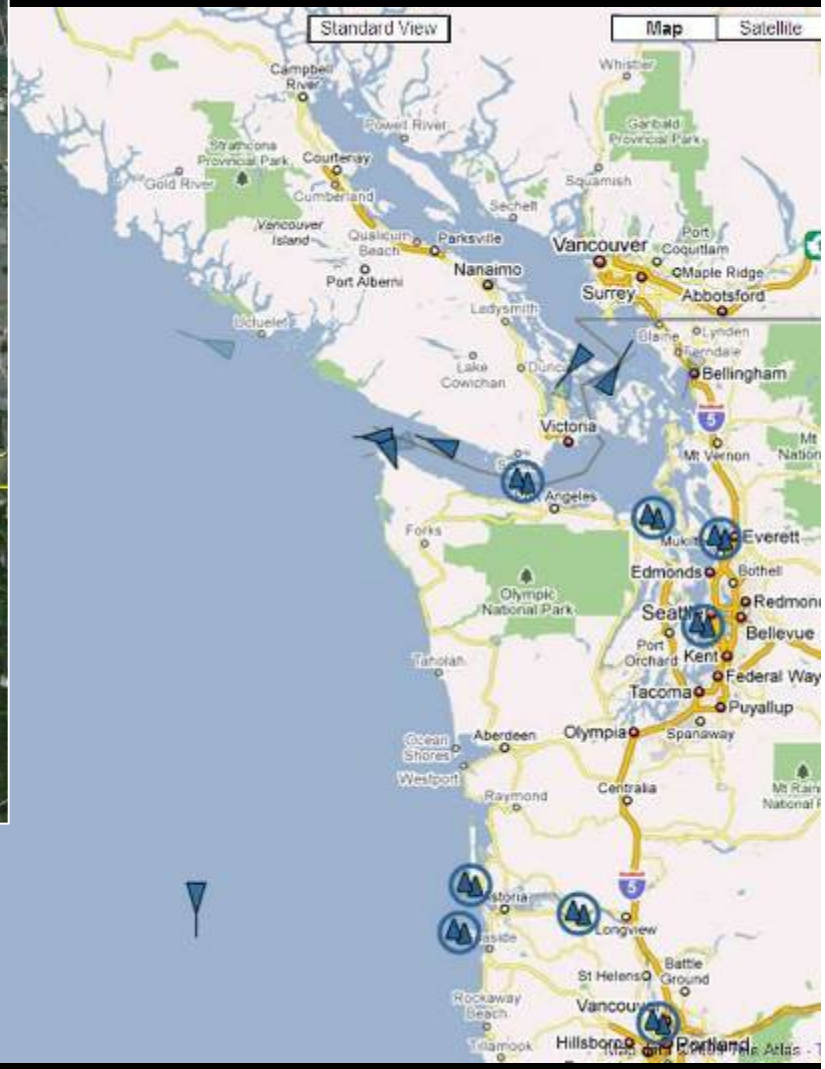

SpaceQuest - 31 unique ships

**31/83 = 37.4%**

# Satellite AIS Augments Terrestrial Data



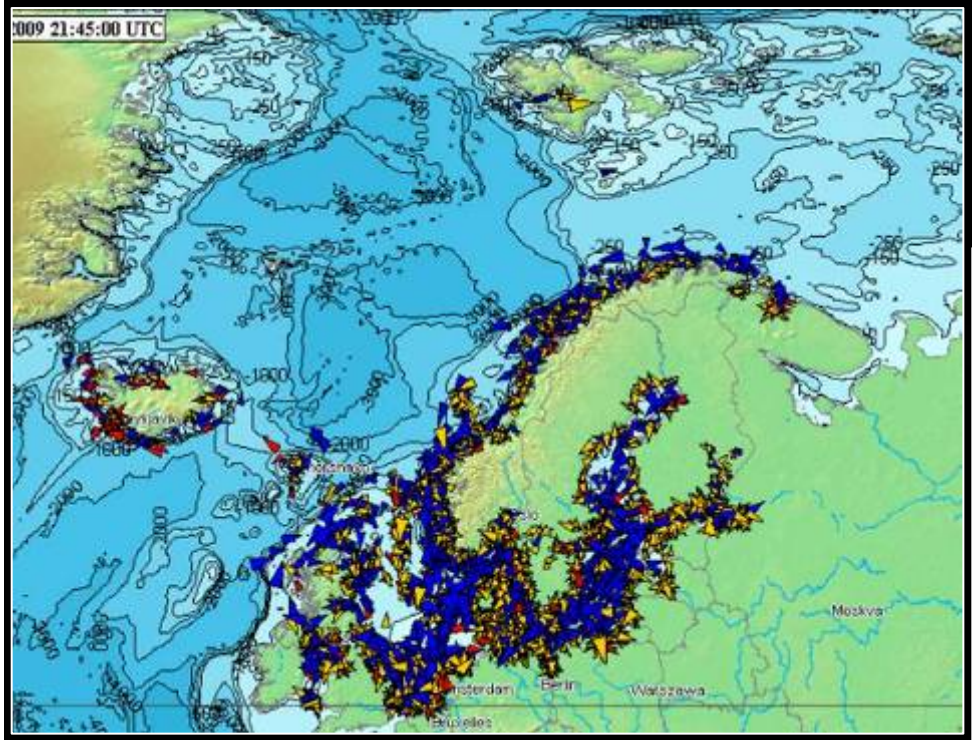

Seattle-Vancouver Area



# Norwegian Terrestrial System Vs. Aprize Satellite

Satellite AIS receivers fill in the coverage gaps of terrestrial receivers.

Terrestrial Readings




Norwegian AIS Data – Courtesy of Bjorn Narheim

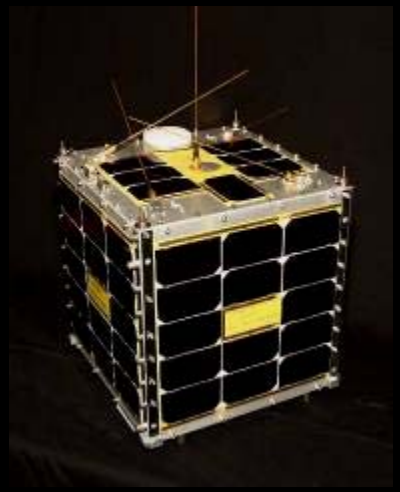
AprizeSat Readings

# SpaceQuest AIS Capability

- Two satellites in orbit with advanced AIS payloads
- One flight-ready AIS satellite test bed for software development
- Space-qualified AIS payload technology
- Operational remote ground station equipment & software
- AIS signal processing algorithm & software implementation
- ITU frequency allocation in 400 MHz band
- National spectrum license issued by Industry Canada
- Partners with antennas suitable for downloading AIS Data
- Export license to launch 10 more satellites from Russian
- Preferred access to future Kosmotras Dnepr cluster launches
- Experience with low-cost satellite construction, launch & operation

# Summary

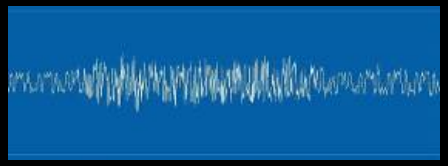
- SQ completed the construction and launch of two AIS satellites in 10-months.
- AIS data collection was activated on the second orbit following separation.
- AprizeSat-3 and 4 are providing high-fidelity AIS signals and packets worldwide.
- Data quality and density appear suitable for commercial & government use.
- Hourly updates are possible with daily 9-hour gaps in coverage.
- The next two AIS satellites will reduce coverage gaps to 4-hours.
- SpaceQuest's AIS payload performance can be significantly improved.



# Some Conclusions

- Effective AIS payloads and satellites can be constructed and launched quickly and affordably.
- AIS data collected from space complements shore-based receivers.
- In spite of the numerous collisions it is possible to recover a significant number of AIS messages in real-time from space.
- Multiple ground stations strategically located can download all global AIS packets at data rates of 38.8 Kbps or less.

# Next Steps



- Enhance satellite AIS data processing to eliminate duplicate records, compress files and encrypt data.
- Set up automated AIS data collection, downloading and distribution.
- Construct and launch two more AIS satellites to reduce the gaps in hourly updates.

# Thank You !

- Kosmotras – Successful launch on Dnepr vehicle
- Peter Wilhelm-  Use of NRL Blossom Point S-Band Antenna
- Bjorn Narheim – Data from land-based AIS receivers
- Kurt Schwehr – AIS Animation
- Dean Rosenberg – Port Vision data for comparison
- Google Earth